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ABSTRACT

Radiation is a natural energy force that has been a part of the environment since the Earth was formed. It takes various forms, none of which can be smelled, tasted, seen, heard, or felt. Nevertheless, scientists know what it is, where it comes from, how to measure and detect it, and how it affects people. Cosmic radiation from outer space and radioactive elements in rocks and soil contribute to the natural background radiation that has always been around us. There are also manmade sources of radiation, such as dental and medical x-rays, smoke detectors, and materials released from nuclear and coal-fired powerplants. Radiation comes from the activity of tiny particles (atoms) of matter. Atoms are composed of protons, neutrons, and electrons, the arrangement of which distinguishes one atom from another. Atoms of different types are called elements. Some of the elements, such as radium, uranium, and thorium are unstable. As they change into more stable forms, they release invisible waves of energy or particles. This emitting of radiation is known as radioactivity. Additional information discussed includes: ionizing types; half-life; your exposure; units of measure; devices for measuring; health effects; limits; nuclear powerplants; and uses. (RT)

Nuclear Energy

About the Cover...

As radiation passes through the dense vapor in a device such as the cloud chamber, it leaves behind tiny trails like those pictured here. In addition to cloud chambers, radiation can be detected by other scientific devices such as bubble chambers, film badges, and Geiger counters.

UNDERSTANDING RADIATION

Radiation is a natural energy force that has existed on Earth and in the universe since the beginning of time. Radiation takes several forms, none of which can be seen, heard, tasted, smelled, or felt. Nevertheless, scientists know what it is, where it comes from, how to detect and measure it, and how it affects people.

Natural and Manmade Sources of Radiation

We are constantly exposed to cosmic radiation from outer space and radioactive elements in the Earth's rocks and soil. They contribute to the *natural background radiation* that has always been around us. But there are also manmade sources of radiation, such as medical and dental x rays, household smoke detectors, and materials released from nuclear and coal-fired powerplants.

Cosmic radiation from outer space contributes to the level of natural background radiation.

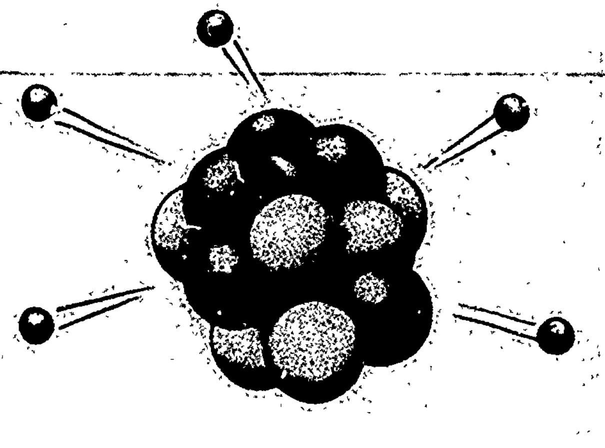
Radiation—The Activity of Atoms

All matter in the universe is composed of atoms, and radiation comes from the activity of these tiny particles. Atoms are made up of even smaller particles (protons, neutrons, electrons), and the arrangement of these particles distinguishes one atom from another.

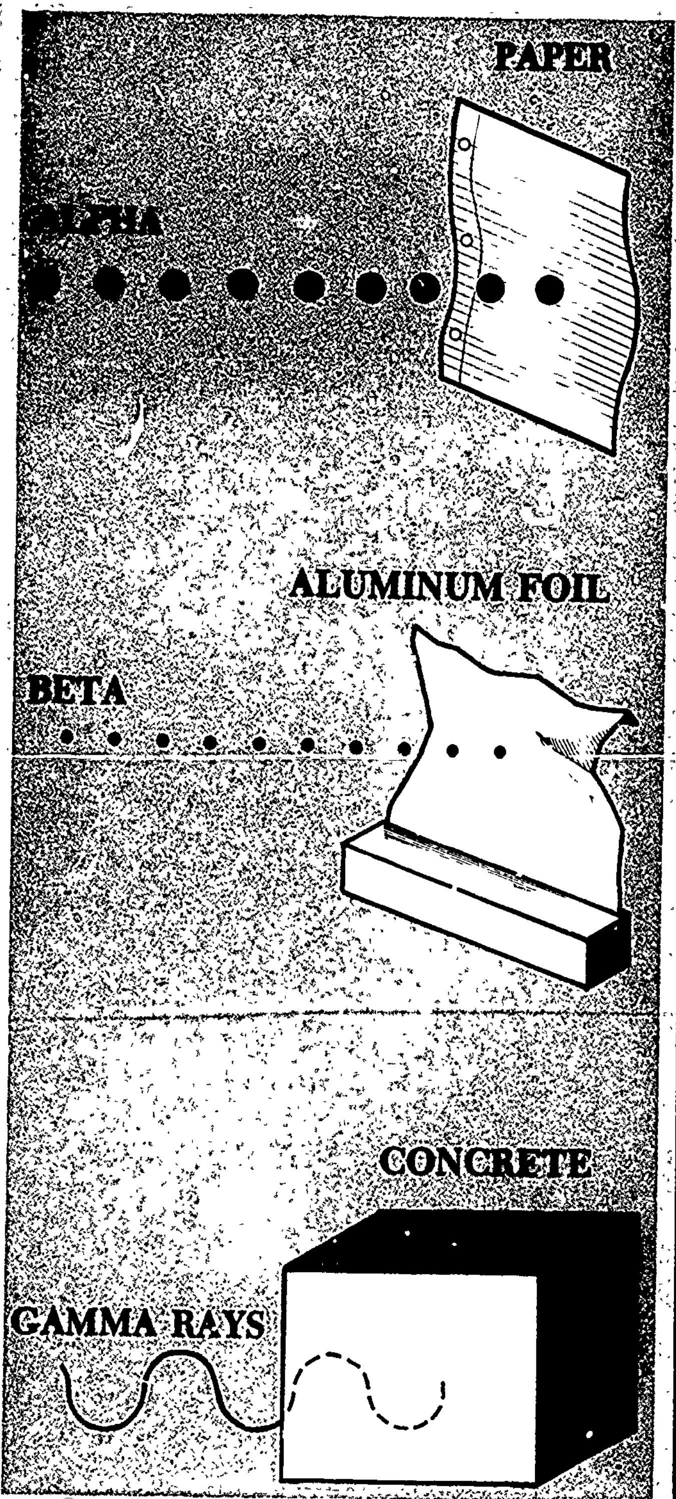
Atoms of different types are known as elements. There are over 100 unique natural and manmade elements. Some of these elements, such as uranium, radium, and thorium, share a very important quality—they are unstable. As they change into more stable forms, invisible waves of energy or particles are released. This is *ionizing radiation*. Radioactivity is the emitting of this radiation.

Ionizing Radiation

Ionizing radiation refers to the fact that this energy force can ionize, or electrically charge, atoms by stripping off electrons. Ionizing radiation can cause a change in the chemical composition of many things—including living tissue.



Radioactive atoms release an invisible energy called ionizing radiation.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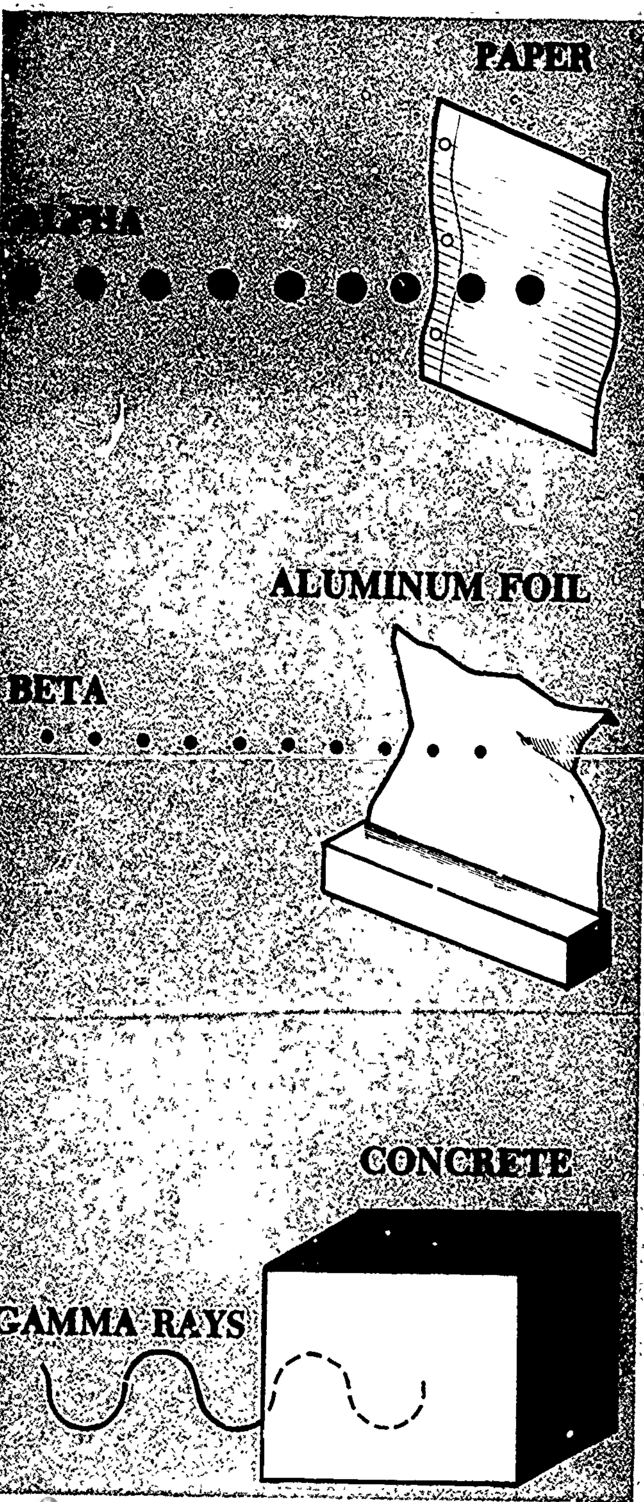
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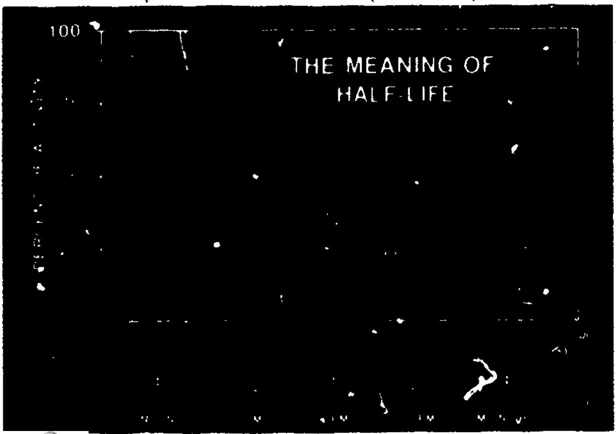
Radioactive "Half-Life"

The radioactivity of a material decreases with time. The time it takes a material to lose half of its original radioactivity is its *half-life*. For example, a quantity of iodine-131, a material that has a half-life of 8 days, will lose half of its radioactivity in that amount of time. In 8 more days, half of the remaining radioactivity will be lost, and so on. Eventually, the radioactivity will essentially disappear. Each radioactive element has a characteristic half-life. The half-lives of various radioactive elements may vary from millionths of a second to millions of years.

As a radioactive element gives up its radioactivity, it often changes to an entirely different element—one that may or may not be radioactive. Eventually, a stable element is formed. This transformation may take place in several steps and is known as a *decay chain*. Radium, for example, is a naturally radioactive element with a half-life of 1,622 years. It emits an alpha particle and becomes radon, a radioactive gas with a half-life of only 3.8 days. Radon decays to polonium and, through a series of steps, to bismuth and ultimately to lead.



Radiation—Units of Measure

Scientists and engineers use a variety of units to measure radiation. These different units can be used to determine the amount, type, and intensity of radiation. Just as heat can be measured in terms of its intensity or its effect using units like calories or degrees, amounts of radiation can be measured in curies, rads, and rems.

The unit used most often to measure the radiation exposure for a person is the millirem (mrem), which is one-thousandth of the basic unit, rem (see definition below). The millirem is used because there are usually only very small amounts of radiation to measure.

[illegible] Marie and [illegible] sample of [illegible] of 1 gram of [illegible]

[illegible] effects of sunlight [illegible]

[illegible] pico [illegible] (trillionth)

The Amounts We Do Receive

Most Americans receive a total of about 200 mrem per year from all sources of radiation—both natural and manmade. About 25 mrem per year of radiation comes from the natural radioactivity in our own bodies. Most of our exposure to natural background radiation comes from cosmic radiation from outer space and from radioactive materials in the Earth's rocks and soil. The actual amount of background radiation depends on the location, elevation, rock and soil content, and weather conditions. For example, a person living in Dallas, Texas, receives about 80 mrem of natural background radiation per year, while a person in Denver, Colorado, receives about 180 mrem. The difference is due to Denver's higher elevation. The higher the elevation, the thinner the atmosphere. This means that less cosmic

CALCULATE YOUR RADIATION EXPOSURE

Take this quiz to find out how much radiation you receive each year.

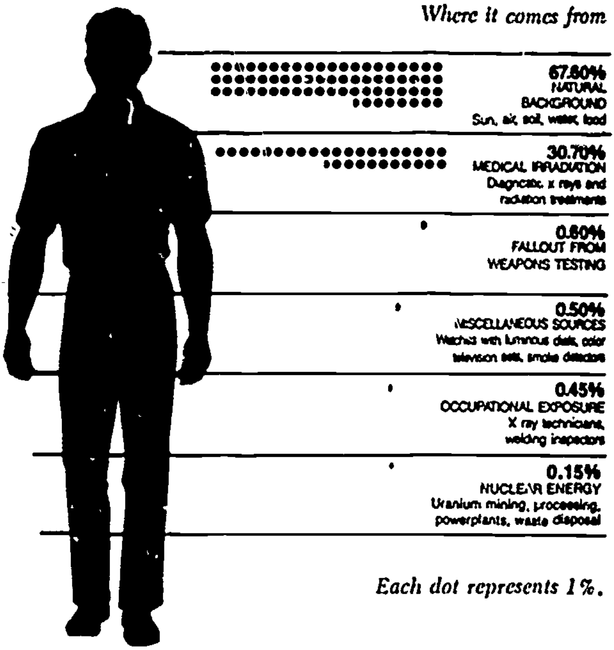
Radiation from the Sun and outer space reaching the Earth.	[illegible]
Some radiation is screened by the atmosphere. Look up the elevation of the place where you live and add 1 for every 100 feet above sea level. (Examples: Pittsburgh is 1,200 feet; add 12. Denver is 5,300 feet; add 50. Atlanta is 1,050; add 10)	____
Building materials are radioactive. If your house is: brick or concrete, add 70.	____
wood, add 30.	____
Ground radiation (U.S. average).	[illegible]
Water, food, air radiation (U.S. average).	[illegible]
Fallout from atmospheric nuclear weapons tests (before 1963).	4
For each person that you spend 8 hours per day with, add 0.1.	____
Add 14 for each dental x ray you've had this year.	____
For each 1,000 miles you've flown in a jet airplane during the year, add 1.	____
If you live within 5 miles of a nuclear or coal-fired powerplant, add 0.3.	____
If you live more than 5 miles from a nuclear or coal-fired powerplant, add 0.	____
YOUR YEARLY TOTAL	____

radiation is filtered out by the atmosphere. Colorado also has substantial uranium deposits. The naturally radioactive minerals in the rocks and soil there contribute to the higher level of background radiation.

Building materials such as brick and stone contain radioactive elements. In parts of New York City's Grand Central Station, the radiation level is equivalent to 525 mrem of background radiation per year. This is because Grand Central Station is built from granite that contains a very small amount of uranium.

We are also exposed to manmade sources of radiation, principally dental and medical x rays, medical tests, and radiotherapy used in treating disease. For the average American, about one-third of the radiation we receive comes from medical sources.

Your Radiation Exposure
Where it comes from



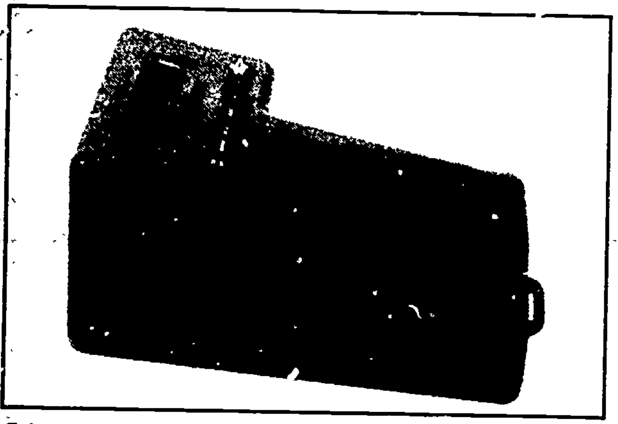
Each dot represents 1%.

Devices For Measuring Radiation

Ionizing radiation cannot be detected by our senses. However, it can be measured and monitored by simple scientific instruments. Two commonly used devices are film badges and Geiger counters.

Film badges are worn by people who routinely work with or around radiation sources. These include workers in medicine, research, industry, and nuclear powerplants. These badges make it possible to determine a worker's exposure to radiation over a period of time because photographic film is exposed by radiation.

To measure radiation levels at any given time, a Geiger counter is used. A Geiger counter contains a special gas-filled tube separating two electrodes. When radiation passes through the tube, a pulse of



Geiger Counter

electric current jumps from one electrode to another. This causes an electrical pulse that can be measured on a meter or by audible clicks. The number of pulses in a given time is a measure of the intensity of radiation.

Radiation Limits

The amount of manmade radiation that the public may be exposed to is limited by Government regulations. Most people in the United States receive radiation doses of 15,000 mrem or less over their entire lifetimes. Although most scientists believe that radiation absorbed in small doses over several years is not harmful, U.S. Government regulations assume that the effects of all radiation exposures are cumulative.

The exposures to the general public from the nuclear fuel cycle are limited by the Environmental Protection Agency to an annual exposure of 25 mrem in addition to the natural background and medical radiation normally received. For people working in an occupation that involves radiation, regulations forbid exposures above 5,000 mrem in any one year.

Nuclear Powerplants

Nuclear powerplants are fueled by uranium. Uranium is used as a fuel because, under precise conditions, uranium atoms can be split apart, releasing large amounts of energy in the form of heat. This process is known as *nuclear fission*. In a nuclear reactor, uranium atoms are split apart in a controlled, continuous process called a *chain reaction*. The heat from the chain reaction inside the reactor is used in a powerplant to turn water into steam, which drives a turbine-generator to produce electricity.

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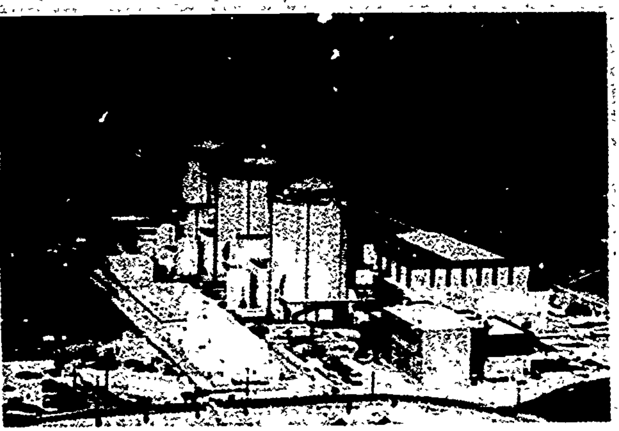
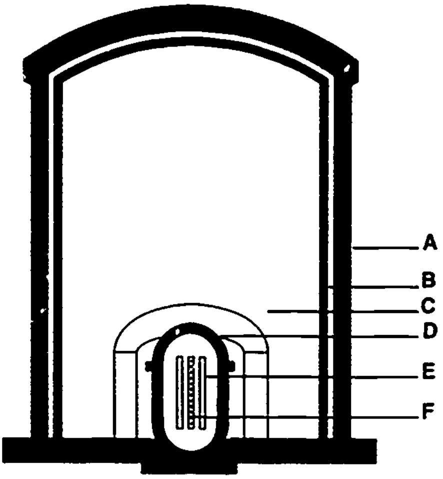


Oconee Nuclear Plant (Duke Power Co.)

The nuclear fuel inside an operating nuclear reactor is highly radioactive. For this reason, radioactive materials are sealed inside ceramic, encased in metal, and held inside a heavy steel reactor vessel during operation. Nuclear powerplants are also built with multiple protective barriers, including a massive concrete-and-steel containment building, to prevent the radioactive materials inside the reactor from entering the environment in the event of an accident.

Radiation guidelines for nuclear powerplants have been established by the Nuclear Regulatory Commission, an independent Government agency. Nuclear powerplants licensed for commercial operation are designed to limit the maximum annual radiation exposure at the plant's boundary to no more than 5 mrem above the natural level. In practice, however, nuclear powerplants release only a tiny fraction of the amount permitted by regulations.



Nuclear Powerplant Safety Barriers

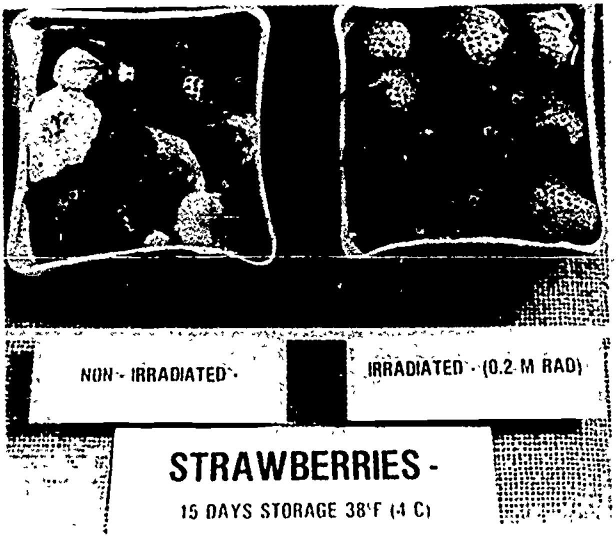
A. Massive steel-reinforced concrete containment building provides a final safety barrier against radiation escape.
B. Leak-proof steel liner surrounds the nuclear reactor.
C. Steel-reinforced concrete well supports and contains the pressure vessel.
D. Steel pressure vessel encases the fuel core.
E. Sealed zirconium metal tubes confine the fuel.
F. Ceramic fuel pellets trap and hold radioactive materials.

Electricity has been generated commercially from nuclear powerplants for nearly three decades. No member of the public has ever been injured or killed by the operation of a commercial nuclear powerplant in the United States. Nuclear powerplant safety compares favorably with other methods of producing electricity.

Using Radiation

Radiation is one of the many energy forces of nature that has been used for the benefit of mankind. With it, major contributions have been made possible in the fields of medicine and industry. The use of radiation requires special precautions, but many benefits are possible with its responsible use. Medical

Techniques using radiation have applications in a variety of other fields. Such techniques are used to test the authenticity of artwork. Radiation can be used to prevent the spoilage of certain foods. This procedure does not reduce the nutritional value of the food or cause it to become radioactive. Archaeologists use a nuclear technique involving the radioactive decay of carbon, known as carbon-14 dating, to date prehistoric objects accurately.



Radiation is used to prevent certain foods from spoiling.

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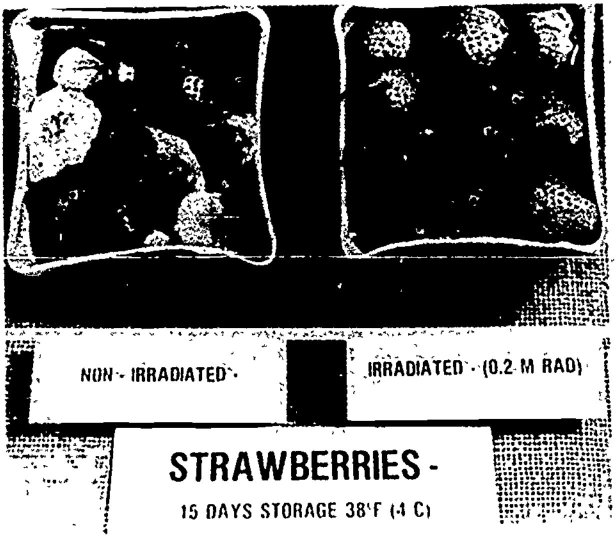

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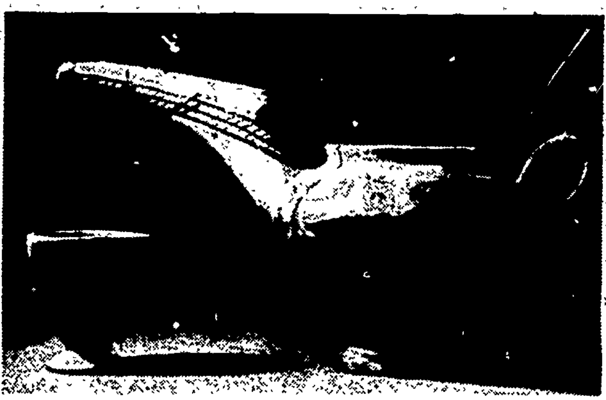

Nuclear techniques can be used to date archaeological finds.

Radiation—The Natural Energy Force

Radiation has been a part of our environment since the Earth was formed. Yet, only in the last century have we known of its existence. Since then, it has become one of the most widely studied and best understood of all natural phenomena. Radiation is now routinely used in medicine, in the laboratory, and in industry. Because the effects and potential hazards of radiation are well understood, we have realized the need to monitor and control the amounts of radiation we receive. Our knowledge of radiation has enabled mankind to improve the quality of life.

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